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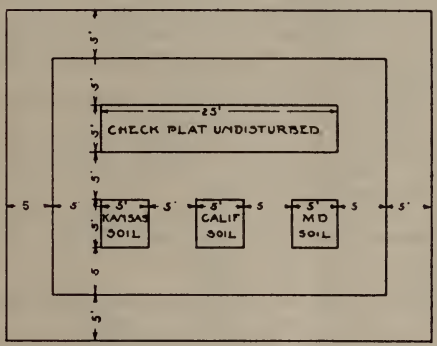
A Progress Report upon Soil and Climatic Factors Influencing the Composition of Wheat

By G. W. SHAW and E. H. WALTERS



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A PROGRESS REPORT UPON SOIL AND CLIMATIC FACTORS INFLUENCING THE COMPOSITION OF WHEAT.

By G. W. Shaw and E. H. Walters.*

For many years the effect of environment upon the composition of grain has been the subject of much study by numerous investigators. The results of these investigations have been quite contradictory, and have resulted in a very wide divergence of opinion as to the factors which influence the gluten content of wheat. In practically all of these studies, the plan has been to transfer the seed from one point to another and grow it under a variety of conditions, and from the results so obtained attempt to draw conclusions as to the influence of environment upon the composition of the grain. In summarizing the reports of previous investigators in this field one notices that no experiments have been conducted under conditions which would eliminate all the varying factors, with the exception of the composition of the soil itself. In the experiments here reported, wheat from the same seed was grown under the same conditions on soils of widely different origin put under the same field influences, thus establishing the condition referred to above.

Many valuable practical results have been obtained from a study of soil fertility in connection with the chemical composition of the crop. But in the attempt to establish a relationship between the chemical composition of the soil and that of the crop grown upon it many difficulties arise. Soils contain varying amounts of the elements of plant food. In one soil these constituents may be in a form which can be readily assimilated by plants, while in another soil they may be present in sufficient quantities, but not in accessible forms. The utilization of one ingredient by a plant may be aided or retarded by the presence or absence of other soil ingredients. For example, in discussing the lime content of soils, Hilgard[1] shows that low percentages of phosphoric acid, nitrogen, and potash in the soil prove adequate in the presence of high amounts of lime. The physical and biological conditions of the soil, and the variations in climate and soil moisture, may also influence the assimilation of the plant food contained in the soil. With such complexities, the attempt to draw any definite conclusions from the results of a single investigation would be to depart from the correct scientific method.

* Note.—The bibliography of this paper and the chemical work relating to the second series of plats was done by Mr. Walters as a portion of his work for master's degree. The work relating to the first series of plats was done by the regular station officers.

[1]Hilgard's "Soils," p. 365.

This study is considered in two parts. Part one is historical, and an attempt is made to bring together some of the most important results of previous investigations already published. The literature devoted to this subject is voluminous, and this paper by no means attempts to quote from all of them. The writers believe, however, that it fairly represents the work relating to the particular phase of the subject discussed herein. Part two is devoted to the experimental phase of the study, the exact nature of which will be discussed in its proper place.

PREVIOUS RESEARCHES.

Plants are so sensitive to a change of environment that it is difficult to say which of the environmental factors have the greatest influence. Many investigators seem to think that the climate has the greatest effect upon the composition of the crop. Others believe that the soil has the greatest influence. It is a well known fact that true varieties, when grown in the same environment, have a tendency to produce a like product regardless of the original soil.[2]

In 1882, Richardson[3] commenced a study of the influence of environment on cereals, which consisted in growing crops from seeds of the same kind and of known composition in different localities. His results show that seeds of different varieties of wheat when grown in Colorado produced a crop which contained a higher protein and a lower carbohydrate content than the original seed. He also observed that the same seed, when grown in California, Oregon, and North Carolina, produced crops with a lower percentage of carbohydrates than the original seed. He concluded from the data obtained that the soil played the most important part in producing these changes.

Wiley,[4] in an article discussing the work of Richardson and reporting the work of later experiments, arrives at a different conclusion and states that the soil has the least effect of the environmental factors, provided, of course, that it contains the proper amounts of plant food, but that the length of the growing season is the most effective factor.

In 1884, Lawes and Gilbert[5] showed that a wider variation occurred in the potash and phosphoric acid content of the ash of wheat with the same manure in different seasons than under three very different conditions of manuring. This point is brought out very clearly in Table I, which is taken from their report.

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[2]LeClerc, Bul. 128, Bureau of Chemistry, U. S. Dept. of Agr., Indiana Sta. Bul. 61, p. 60.

[3]Buls. 1, 4, and 9, Bureau of Chemistry, U. S. Dept. of Agr.

[4]Yearbook, U. S. Dept. of Agr. 1901, p. 299.

[5]Jour. Chem. Soc., London, 1884, XLV, p. 304.

TABLE I.

Highest, lowest, and mean percentage of potash, and phosphoric acid in the pure ash in sixteen consecutive seasons.

Plot.	Fertilizers.	Per cent in dry matter of grain		
		Highest.	Lowest.	Mean. 16 years.
	Potash.			
2	Farmyard manure	0.779	0.538	0.635
3	Unmanured	0.838	0.601	0.662
10a	Ammonium salts, alone	0.738	0.515	0.602
	Phosphoric acid.			
2	Farmyard manure	1.110	0.965	1.044
3	Unmanured	1.075	0.898	1.003
10a	Ammonium salts, alone	1.003	0.718	0.854

Considering the weight per bushel as the single factor in determining the quality of the crop, the same authors observed that the best crops are associated with low percentages of total mineral constituents (ash) and a low percentage of nitrogen in the dry substance. Accordingly, grain of high quality is associated with a high percentage of carbohydrates. In every case the lowest weight per bushel was associated with the lowest yield. Table II expresses some of their results.

TABLE II.

Maximum, minimum, and mean yields of each plot during sixteen years with the percentage composition of the crop.

Plot.	Weight per bushel.	Pounds grain per acre.	Percentage composition in dry matter of grain.						
			Ash.	Nitrogen.	Phosphoric acid.	Sulphuric acid.	Lime.	Magnesia.	Potash.
2	63.8	2068	1.93	1.58	0.97	.029	.049	.203	.637
2	51.1	1120	2.20	1.76	1.03	.052	.057	.223	.779
Mean	57.4	1967	2.06	1.96	1.07	.014	.054	.229	.640
3	62.7	1127	1.95	1.65	1.00	.013	.052	.212	.628
3	45.9	359	2.36	2.09	1.08	.057	.073	.243	.838
Mean	54.3	823	2.08	1.98	1.04	.029	.058	.217	.670
10a	62.6	2587	1.56	1.70	0.72	.037	.060	.175	.537
10a	48.6	642	1.98	2.43	0.88	.049	.074	.185	.709
Mean	53.7	1147	1.91	2.25	0.90	.039	.068	.205	.632

A study of Table II will show that in every case the ratio of nitrogen to phosphoric acid is greater in the crop of minimum yield, viz., an increase in the yield is associated with a decrease in the ratio of nitrogen to phosphoric acid. In the crop of minimum yield the percentage of ash, and therefore ash constituents, was higher than in the largest crop.

The results of grain grown on plots receiving very different manures but all under the same seasonal conditions are expressed in the following table:

TABLE III.

Analysis of wheat grown on plots receiving different manures.

Plot.	Weight per bushel.	Pounds dry matter per acre.	Percentage composition of dry matter in grain.						
			Ash.	Nitrogen.	Phosphoric acid.	Sulphuric acid.	Lime.	Magnesia.	Potash.
2	60.6	1963	1.96	1.80	1.038	.011	.050	.228	.593
3	58.5	836	2.01	1.85	1.035	.017	.054	.219	.630
5a	59.6	975	2.02	1.74	1.051	.013	.056	.222	.635
10a	58.4	1443	1.75	2.08	0.846	.031	.066	.199	.565
11a	59.0	1773	1.85	1.92	0.944	.020	.071	.205	.568
12a	60.1	2014	1.86	1.83	0.947	.019	.059	.203	.596
13a	60.2	1963	1.86	1.85	0.952	.015	.054	.203	.601
14a	60.0	2028	1.85	1.87	0.952	.018	.054	.209	.585
7a	59.6	2062	1.88	1.87	0.962	.010	.052	.218	.599

The different plots were fertilized as follows:

2. Farmyard manure.
3. Unmanured.
5*a*. Mixed mineral manures.
10*a*. Ammonium salts.
11*a*. Ammonium salts and superphosphate of lime.
12*a*. Ammonium salts, superphosphate and sulphate of soda.
13*a*. Ammonium salts, superphosphate and sulphate of potash.
14*a*. Ammonium salts, superphosphate and sulphate of magnesium.
7*a*. Mixed mineral manures and ammonium salts.

It will be noticed that with one exception, plot 5*a*, the nitrogen content is fairly uniform. Plot 5*a* received mineral manures alone and was deficient in nitrogen. On plot 10*a*, which received ammonium salts, and, therefore, an abundant supply of nitrogen, the nitrogen content was high and mineral constituents low. It will also be seen that the crop grown on plot 11*a*, which received applications of lime, contained a higher lime content than the crop grown on any of the other plots. On a whole the ash constituents show a marked uniformity. It appears, however, that they are directly influenced by their supply or exhaustion in the soil. *On a close study of their results the composition of the crop seems to reflect that of the soil.*

Von Liebenberg[6] and E. Von Proskowetz in 1893 found from fertilizer experiments in connection with the chemical analysis of the soil that the yield depends, not only upon an adequate supply of plant food in the soil, but upon the relation of nitrogen to phosphoric acid, the yield being higher the greater the proportion of nitrogen present.

Their results show that the ratio of nitrogen to phosphoric acid is greater in the crop than in the soil, and that the supply of nitrogen in the soil is drawn upon much more largely than that of phosphoric acid.

Schindler[7] stated that the composition of the grain depends upon the fertility of the soil. Also, that *a long growing period from the time of bloom to ripeness caused a low percentage of nitrogen in wheat,* that the

[6]Exp. Sta. Rec. (1893) Vol. V., p. 702; Abst.
[7]Bot. Centralb. 56 (1893), p. 345; Abst. Der Weisen, Berlin.

weight of the grain is affected by climate, and that the relation between the protein and carbohydrates is affected by the length of the growing period.

Cross and Smith[8] concluded from their investigations of the chemical history of the barley plant that *the condition of soil nutrition had little influence upon the composition of the plant.* "The plant, in other words, is, as regards soil nutrition, constant or invariable in respect to the relation of its products to assimilation."

In 1895 Januszowski[9] from experiments planned to determine the value of the plant analysis in estimating the quality of soil, found the results misleading, since a low phosphoric acid content, for instance, may be due not to the deficiency of that ingredient in the soil but to an excess of potash or nitrogen. He found that the application of phosphoric acid to a soil deficient in that element was followed by an increase in phosphoric acid in the grain grown on the soil, provided the application of phosphoric acid was not accompanied by liberal manuring with nitrogen.

Liebscher and Edler[10] noticed that the application of nitrogenous fertilizers increased the nitrogen content of oats, and that the exclusive application of potash caused a decrease in nitrogen and an increase in potash in the plant. With a complete fertilizer, the percentage of potash was lowest.

In studying the effect of humus on the percentage of nitrogen in oats, Wiley[11] conducted pot experiments which consisted in growing oats in peaty soil without manures and with various manures. The soil contained on the average less than 10 per cent of mineral matter, about 2.5 per cent of nitrogen, and very little potash and phosphoric acid. The crop was very high in nitrogen, of which much was present as amid nitrogen due to direct absorption from the soil. *The protein nitrogen remained within the limits of the usual amounts obtained in ordinary soil.* Potash and nitrogenous manures in the amounts applied had no effect upon the yield. Phosphates increased the yield and lowered the percentage of nitrogen, probably due to increased crop.

Von Seelhorst and Panaotovie[12] in 1889 observed that the nitrogen and ash constituents of cereals increased with an increase in space between the plants. In other words, within certain limits the nitrogen and mineral constituents in cereals vary directly as the feeding surface of the plants.

Bogdan[13] found that the increase of the salt content of alkali soils caused an increase in the nitrogen and ash contents of the grain grown

[8]Chem. News, 72 (1895) No. 1883, p. 307.
[9]Bied. Centr., 1895, vol. 28, p. 27.
[10]Jour. Landw., 1896, p. 84.
[11]Landw. Versuchs. Stats. 1897, vol. 49, p. 193.
[12]Jour. Landswirtschaft, 1899, vol. 47, p. 379.
[13]Exp. Sta. Rec. (1902) XIII, p. 329.

therein due to the fact that the absolute weight of the grain diminished. This, he says, explains the high protein content of wheat from the east and southeast of Russia, where the soils are rich in nitrates and other soluble salts.

Godlewski[14] in 1901 observed that in the case of potatoes the insufficiency of potash in soil narrowed the ratio of potash to phosphoric acid and of potash to nitrogen in the tubers. The inadequate supply of nitrogen caused the widening of the ratio of potash to nitrogen and narrowed the ratio of nitrogen to nearly all ash constituents. A low nitrogen content of the soil narrowed the ratio of nitrogen to phosphoric acid in barley straw without affecting the relation of the nitrogen to the other elements, while an insufficient amount of phosphoric acid widened the ratio to 5.1, and is considered as indicating lack of phosphoric acid in the soil. An adequate supply of potash in the soil reduced the potash content of barley straw to less than 1 per cent in the dry matter, increased the amount of nitrogen, lime, and magnesia, and narrowed the ratio of potash and phosphoric acid to magnesia. The normal relation of potash, nitrogen, phosphoric acid, lime, and magnesia in barley straw is given at 100, 50, 30, 40, and 10. The author showed that plants growing in a soil deficient in available plant food of any kind will, in their ash, show a corresponding deficiency, or at least a minimum proportion of the same; and that in many cases the nature of the deficiency manifests itself in the form or development of the plant so nearly as to render chemical analysis unnecessary.

In 1901, Tollens[15] stated *that no definite relation existed between the chemical composition of the ash of plants and the soil in which they were grown.* The stage of growth, the available moisture, the thickness of the stand, the soil, and the fertilizers, are all important factors in producing the variations in the composition of the ash of plants.

Wilfarth and Gcell[16] found that increasing amounts of potash in the soil produced corresponding increased amounts of that ingredient in the plant.

Whitson, Wells, and Vivian,[17] in studying the influence of soil on the protein content of crops, conducted field and pot experiments with corn, oats, barley, rape, and cowpeas. The crops were grown on soils of different degrees of fertility, and nitrogen determinations were made at frequent intervals in the soil and in the crops. In one instance, the nitrogen content of oats grown on soils having the same physical composition, but different degrees of richness in nitrates, was 1.93 per cent on the poorest soil, 2.53 per cent on the medium soil, and 2.66 per cent on

[14]Exp. Sta. Rec. (1902) XIII, p. 637; Abst.
[15]Exp. Sta. Rec. (1901) XII, pp. 207 and 305.
[16]Exp. Sta. Rec. (1902) XIII, p. 1030; Abst.
[17]Wis. Exp. Sta. Report, 1902, p. 192.

the richest soil. In a similar test with corn, the figures were 1.35, 1.59, and 1.80, respectively. The results of the experiments, as a whole, indicated that crops vary greatly in their nitrogen contents at the same stage of development, and that this variation may exist even when crops are making practically equal growth. Under similar seasonal conditions the amount of nitrates in the soil is believed to be the most important factor in causing this variation. The results show a marked relation between the amount of available nitrogen in the soil and the nitrogen content of the plant. The data collected indicated that the richness of the soil determines the yield more than does the climate. The latter determines the length of the growing period and the immunity from early or late frosts and the possibility of bringing the plant to maturity.

Wilfarth and Wimmer[18] observed that a deficiency of nitrogen in the soil caused an increase in the percentage composition of carbohydrates, and a decrease with a deficiency of phosphoric acid.

Soule and Vanatter[19] stated *that a rich soil, or the use of fertilizers, did not seem to increase the protein content of wheat to any appreciable extent.*

Stahl-Schroder[20] found, from a series of experiments with oats on heavy and light soils with different fertilizers, that *the composition of the seed varies considerably with the season* and with the character of the soils, but is not appreciably affected by the variety, or time of planting. He concluded that the analysis of the seeds as a means of determining the assimilable food in soils gives results which are of local value only.

Hall[21] states that *the soil is the least effective environmental factor in producing variations in the composition of wheat,* this statement being based upon data obtained from experiments with oats grown in pots containing six soils of very different characters, which showed that no strict agreement existed between the composition of the ash of the plants and of the soil. The variations in the composition of crops grown in duplicate pots of the same soil were very often greater than between those grown on different soils.

Von Seelhorst and Fresenius[22] observed, from experiments with oats, that the nitrogen content of oat straw was decreased when the amount of moisture applied to the plants was increased.

In 1902, Widtsoe[23] showed that the protein content of wheat increased very markedly as the amount of water applied to the soil decreases. The soil that received 30 inches of water produced wheat containing

[18]Jour. Landw. 51 (1903), p. 129.
[19]Tenn. Sta. Bul. (1903), XVI, No. 4.
[20]Jour. Landw. 52 (1904), 31.
[21]Jour. Soc. of Arts, 1904, 52; No. 2711, 881.
[22]Jour. Landw., 1905, vol. 53, p. 27.
[23]Utah Sta. Bul. 80 (1902), 148.

15.26 per cent of protein; while the wheat produced on soil that received 7.7 inches contained 26.72 per cent. This difference between the wheat grown on non-irrigated land and on land that received 13.79 inches of water was 2.82 per cent.

In 1906, Le Clerc[24] published that the protein content of wheat grown on arid land was higher than when grown on irrigated land. The protein content of wheat, expressed in per cent, grown on irrigated and on adjoining non-irrigated land was 11.1 and 17.7, respectively.

Pingree[25] in studying the effect of various fertilizers upon the composition of oats found that where muriate of potash was applied alone and as part of a complete fertilizer a distinct increase of potash was found in the ash of the plant; also, the application of dissolved phosphate caused an increase of phosphoric acid in the ash of the plant.

Snyder[26] showed that by the proper application of fertilizers the quality of wheat could be improved and thus increase the protein content at least 1 per cent. Some of his results are expressed in Table IV.

TABLE IV.

Protein and ash content of wheat grown on plots receiving different fertilizers.

Kind of fertilizers.	Number of samples.	Protein N x 6.25.	Ash.
Nitrogen	12	13.63	1.58
Potash	12	13.02	1.62
Phosphoric acid	12	12.65	1.73
Complete (N, K_2O, P_2O_5)	12	13.17	1.69
No fertilizer	12	13.04	1.64

It will be noticed that the protein content was highest in the wheat grown on plots receiving a nitrogenous fertilizer, and lowest on plots fertilized only with phosphoric acid.

Stewart and Greaves[27] found that the ash of plants grown in Utah is high, due to the richness of the soil in mineral constituents; and that the nitrogen content of wheat grown on arid land is higher than that of wheat grown on irrigated land, which is in accord with the facts observed by Le Clerc.

[24]Yearbook 1906, U. S. Dept. of Agr., 199.
[25]Penn. State College Report, 1906, 43.
[26]Jour. Am. Chem. Society, 1908, 30: 1, 604.
[27]Utah Sta. Bul. 103 (1908).

EXPERIMENTAL DATA.

In 1905, the California Experiment Station, in collaboration with the Bureau of Plant Industry of the United States Department of Agriculture, undertook an investigation along a similar line, which consisted in growing wheat from the same original seed continuously in each of three localities, viz.: (1) Kansas, Texas, and California; (2) in South Dakota, Kansas, and California.

The crop from the apex of each of these two triangles was sent to each of the other two stations of the same triangle and there grown under the same conditions as the continuously grown seed. Thus, at each station there were three plats all from the same original seed, the seed of the other two plats coming from the other points of the triangle. Two varieties of wheat were thus grown, viz.: Crimean, C. I., 1437 (?). a common wheat of the winter type; and Kubanka, C. I., 1440, a durum variety. The former was grown in California, Kansas, and Texas, the original seed having been grown in Kansas in 1905; the latter in California, Kansas, and South Dakota, the original seed having been grown in South Dakota in 1905. These plantings have been continued until the present year.

Samples were taken each year and analyses made, the detailed analyses as made by Dr. J. A. LeClerc, of the Bureau of Chemistry, United States Department of Agriculture, have been published in Bulletin 128 of that Bureau. The results obtained from analyses of the same samples made at this station are essentially the same as those published by Dr. Le Clerc, and consequently need not be duplicated in the present paper.

The essential conclusions from these analyses are stated by Dr. Le Clerc as follows:

(1) "Wheats of the same variety when grown in the same locality and under the same conditions are, therefore, seen to vary but little in composition, although coming from seed differing widely in physical and chemical characteristics. These results are corroborative of Eckenbrecher's work with barley, and are entirely at variance with Hall's statement that 'each race or variety possesses qualities which are modified only to a slight degree by seed, soil, or climate.'"

(2) "Wheat of any one variety, from any one source, and absolutely alike in chemical and physical characteristics. when grown in different localities, possessing different climatic conditions, yields crops of very widely different appearance and very different in chemical composition."

(3) "The results so far obtained would seem to indicate that the soil

and seed play a relatively small part in influencing the composition of crops."

While the above results seem to indicate that the climatic factor is the principal, if not the only one, affecting the nitrogen content of wheat, yet the experiment was subject to the same sources of error and elements of doubt, as all of the other trials where seed transference had been practiced in the prosecution of studies of this problem, viz., a change of both soil and climate at the same time, thus giving two variable factors, both *climate and soil.*

In 1907, the senior author undertook to neutralize the effect of one of these factors, viz., climate, by securing from Hays, Kansas, a sufficient amount of soil, known to have produced for a number of years high gluten wheat, to make a plat 6 feet long, 3 feet wide, and 3 feet deep. That this Kansas soil was capable of producing a high gluten wheat is evidenced by the protein content of the wheat grown upon it the previous season and forwarded together with the soil. This wheat showed a protein content of 20.06 per cent, as indicated in the table below.

The soil was removed from its original position in the ground in six-inch layers which were shipped in bags to the University Farm at Davis, California, where it was placed in a hole previously prepared to receive it, the soil being placed in said hole in the sequence indicated by the labels, thus bringing the original bottom soil in the corresponding position to that occupied in Kansas, and the same for each other six-inch layer. A second plat was prepared in a similar manner alongside of it by removing the soil from a like area and to the same depth, and replacing the same soil in the hole whence it had been removed. Each of the holes previous to refilling was lined by a rather loose cement lining 1½ inches thick, except the bottom, which was left without lining, the object being to prevent the roots from passing beyond their own area of soil laterally. In placing the soil in the holes, it was dry-tamped to settle it as much as possible, and thus it was allowed to remain until the rain had settled it, after which each plat was cultivated and seeded.

On each of the two plats two types of wheat were grown from 1907 to 1910, inclusive. On one end of each of the plats was placed a high gluten Turkey Red wheat, which grew on the Kansas soil the previous year, and which another table shows carried an unusually high protein content. On the other end of each plat was seeded a low protein California-grown Durum wheat.

By this soil transfer it was intended *to neutralize the effect of climate and have as a variable factor only the soil,* whereas by the seed-transfer method heretofore practiced, there were always two variables and one could never be certain what proportional influence might be due to soil and what to climate in whatever variation occurred in the product.

The writer's idea in using both a low-protein and high-protein grain in this experiment was to secure something of a check, believing that if the soil should prove to be the controlling factor, then the high-gluten Kansas wheat would remain high gluten and fall materially lower upon the California soil, and that the low-gluten California would remain practically the same in the California soil plat and show a marked increase in gluten when grown on the Kansas soil under California climate. The results set forth in the table do not show that the soil has produced any marked effect of this kind.

The Soils.—The two soils used in this experiment show a marked contrast in appearance and in texture. The California soil is the type which is quite general in the Sacramento Valley, and known as a gray silt loam. It has been cropped to grain for many years—at least forty—and is still producing under good culture heavy crops. It is quite inclined to bake and crust if wet upon top and then allowed to dry. It is more inclined to do this than is the soil from Kansas. The Kansas soil is black in color, and carries markedly less sand than the California soil, as will be seen from the subjoined mechanical analysis, this difference in sand being compensated by a corresponding increase in silt, while the clay and fine silt content of the two types is essentially the same. This type would undoubtedly be classed as a silt loam, although it exhibits essentially different properties than the California soil.

The details of the mechanical analysis are shown in the following table:

TABLE V.

Mechanical constituents of soils from Davis and Kansas.

Diameters of sediments.		Percentage, Davis.	Composition, Kansas.
mm.	Clay	19.12	18.26
to .016	Fine silt	40.93	44.56
.016 to .025		3.35	3.20
.025 to .036	Silt	1.34	11.01
.036 to .047		7.75	12.27
.047 to .072		8.78	7.49
.072 to .12	Sand	8.10	1.19
.12 to .16		3.30	.72
.16 to .30		4.15	.46
.30 to .50		3.07	.76
		99.89	99.92
	Summary.		
	Clay	19.12	18.26
	Fine silt	44.28	44.76
	Silt	17.87	30.77
	Sand	18.62	3.13
		99.89	99.92

The chemical composition of the soils as represented by one-foot samples is shown in the following table, the analyses having been made according to so-called official method:

TABLE VI.

Comparison of soils in soil transference.

	First foot.		Second foot.		Third foot.	
	California.	Kansas.	California.	Kansas.	California.	Kansas.
Insoluble matter	76.04	79.79	76.83	80.19	77.80	79.80
Soluble matter	23.96	20.21	23.17	19.81	22.20	20.20
Iron and alumina	15.43	10.57	13.84	10.67	13.40	10.85
Calcium oxid	.85	.88	1.43	.73	.97	1.26
Magnesium oxid	.76	1.22	1.74	2.40	1.58	2.25
Sodium oxid	.14	.22	.27	.44	.25	.33
Potassium oxid	.52	.66	.49	.75	.45	.87
Sulfuric acid	.13	.15	.08	.05	.07	.08
Phosphoric acid	.31	.30	.32	.36	.34	.41
Volatile matter	5.87	6.50	4.83	4.47	5.30	4.11
Total soluble matter	24.04	20.50	23.00	19.87	22.36	20.16
Total nitrogen in soil	.100	.163	.085	.057	.058	.034
Humus in soil	1.54	1.54	1.24	.707	1.70	1.12
Nitrogen in humus	.07	.10	.03	.062	.052	.025

In each foot the total soluble matter in the California soil exceeds that of the Kansas soil. The principal difference in the two appears in the iron-alumina content.

In the top foot, of the essential elements of plant food there appears practically no difference in either lime, potash or phosphoric acid. Both soils appear well supplied with all three of these compounds, and this similarity of composition also extends to the humus, which is identical in amount in the two soils, and to the nitrogen of the humus.

The same general relation holds with reference to the soluble portion of the second foot, the California soil showing 23.17 per cent, as against 19.81 per cent for the Kansas soil. The same general difference holds, also, with regard to the iron-alumina content, but in the matter of lime there is a marked increase in the California soil and a slight decrease in the Kansas soil. There is a distinct increase in the second foot of both soils, but no essential change or difference in phosphoric acid content. The humus content quite markedly decreases in both soils, the California soil showing about one sixth less and the Kansas soil less than one half as much. This same difference shows in the total nitrogen in the soil, but the nitrogen in the humus appears to be higher in the Kansas soil which is also true of the first foot of soil.

In the third foot the Kansas soil shows the larger per cent of lime, also of potash and phosphoric acid, while the total nitrogen in the soil still is the higher in the California soil. In both the California and the Kansas soils there appears more humus in the third foot than in the second foot, but there is still less in the Kansas than in the California soil, although the nitrogen in the humus has decreased by about one half and that of the home soil increased.

Thus, we may sum up the soil difference as follows: A distinctly larger amount of soluble matter in the California soil; the top foot in the two soils essentially the same; in the second foot about twice as much lime in the California as in the Kansas soil; about two sevenths more potash in the Kansas soil than in the California. The California soil carries a distinctly larger amount of soluble matter, but otherwise is essentially the same, except for total nitrogen, in which the Kansas soil exceeds by about one third. It carries double the lime in the second foot, but not only decreases in amount in the third foot, but falls well below the Kansas soil. It carries less potash, but in phosphoric acid does not differ materially. In total nitrogen it exceeds that of Kansas, as it does in humus content.

In the matter of nitrogen the Kansas soil is the better supplied in the top foot, but otherwise the advantage lies with the California soil. Inasmuch as the bulk of the feeding roots of the plant are in the second foot, the California soils seems to have an advantage and this is quite significant when considered with the results obtained from the analysis of the grain grown on these two plots.

FIELD NOTES.

Field notes and observations for the two seasons here reported were made as follows:

TABLE VII.

Showing field notes on soil exchange wheats. (Exp. D-5.)

	Season 1907-8.				Season 1908-9.			
	Kubanka—Low gluten.		Turkey Red—High gluten.		Velvet Don—Low gluten.		Turkey Red—High gluten.	
	Davis soil.	Kansas soil.	Davis soil.	Kansas soil.	1063 Davis soil.	1062 Kansas soil.	Davis soil.	Kansas soil.
Date planted	January 27	January 27	January 27	January 27	December 17	December 17	December 17	December 17
Came up	February 16	February 16	February 16	February 16	January 6	January 6	January 6	January 6
Headed	May 14	May 16	May 7	May 6	May 6	May 5	May 14	May 13
Uniformity of heading	80	75	60	80	90	95	85	90
Bloomed	May 17	May 19	June 21	June 10				
Ripened	June 26	June 28	July 16	July 16	June 24	June 22	June 26	June 24
Harvested	June 29	June 29	July 17	July 17	June 24	June 24	June 26	June 24
Number days to maturity	132	134	152	152	169	167	171	169

TABLE VIII.

Analysis of wheat grown on soil exchange plats, Davis, California. (Exp. D-5.)

	Season of 1907-08.						Season of 1908-09.					
	Kubanka Durum—Low gluten.			Turkey Red—High gluten.			Velvet Don—Low gluten.			Turkey Red—High gluten.		
	Original Lab. No. 1071	California soil No. 1072	Kansas soil No. 1073	Original No. 981	California soil No. 981 A-C	Kansas soil No. 981 A-K	Original No. 1061	California soil No. 1063	Kansas soil No. 1062	Original No. 981	California soil No. 981 B-C	Kansas soil No. 981 B-K
Total protein	10.56	15.14	15.07	20.06	18.29	18.02	9.43	13.23	12.95	20.06	15.07	14.32
Ash	2.05	1.88	1.65	2.47	-------	2.21	2.02	1.74	1.65	2.47	2.02	1.88
Fat	2.84	2.30	2.53	2.09	-------	1.97	2.50	2.23	2.41	2.09	1.87	2.08
Fiber	2.43	3.25	3.37	2.24	-------	2.15	3.02	3.54	3.32	2.24	2.68	2.31
Pentosans	6.60	7.63	-------	7.70	-------	-------	7.80	7.00	7.76	7.70	7.64	7.16
Sugars	2.64	3.93	-------	-------	-------	-------	3.11	3.54	3.10	-------	4.31	4.31
Alcohol; soluble nitrogen	.68	1.18	1.23	1.44	1.14	.98	.78	.95	.98	1.44	1.14	1.17
Salt; soluble nitrogen	.69	.62	.73	.83	-------	.70	.47	.62	.55	.83	.72	.64
Percentage typical kernels	19.54	98.00	99.30	100.00	100.00	100.00	82.01	79.60	71.8	100.00	99.10	98.78
Percentage starchy kernels	80.46	2.00	.70	-------	-------	-------	17.99	20.40	28.2	-------	.90	1.22
Kernels in 10 grams	220	203	189	144*	363	340	239	227	231	141	266	262
Days to mature	-------	131	133	-------	151	151	-------	169	167	-------	171	169

*Slightly pinched.

In the season of 1907-08 it will be noted that the Durum wheat (Kubanka) headed two days later on the Kansas soil than on the home soil, and that it also matured two days earlier on the Davis soil. In the case of the Turkey Red grain, if there was any difference in rapidity of growth, it was in favor of the Davis soil; but the grain matured in both soils in the same time, viz., 152 days.* These plats were apparently under as uniform a condition in the field as it was possible to make them.

Field notes for the season of 1908-09 do not show that the conditions of growth were as uniform as in the preceding season. During this season the rate of growth was slightly greater upon the Kansas soil. On May 5th, the Turkey Red wheat was 2 feet 6 inches tall on the Kansas soil, but only 2 feet 3 inches on the Davis soil, and a similar difference held for the Durum wheat also. The mass of growth was also somewhat heavier on the Kansas soil plat.

At harvest the Durum wheat gave the following yield upon each of the plats:

	Davis soil.		Kansas soil.	
	Number of plants.	Weight.	Number of plants.	Weight.
Border plants	35	2 lb. 11 oz.	29	3 lb. 3 oz.
Interior plants	45	3 lb. 11 oz.	52	5 lb. 8 oz.
Total	80	6 lb. 6 oz.	81	8 lb. 11 oz.

The Turkey Red wheat was not weighed.

The results of analyses for these plots are expressed in Table VIII.

VARIATIONS IN NITROGEN CONTENT.

Since the nitrogenous ingredients of wheat are of the chief importance, the principal attention will be directed toward these in the discussion. In the case of the low-protein original, each of the soil plats produced in 1907-08 grain of higher protein content than the original by about 4.5 per cent, thus indicating a very marked seasonal influence. In this connection it should be stated that the entire grain crop of the Sacramento Valley in that season showed a higher gluten content than it did in the preceding season, and this becomes quite significant when considered with the other data bearing on this question. Comparing the grain produced upon the two types of soil, it is easily seen that there is no practical difference in total protein between the two lots, showing as they do 15.14 per cent and 15.07 per cent, respectively, for California

*This time is reckoned from the date of coming up to the date of ripening.

and Kansas soils, these soils being under the same climatic conditions, the very slight difference being entirely within the range of analytical error. What slight difference there is, however, is in favor of the California soil. If we turn to the trial with the high-protein original (981) grown in Kansas, it is clear that, while under the California climate there has been a lowering of the total protein on this soil by about 2 per cent, yet *this has taken place both on the California plat and the Kansas plat by practically the same amount, there being only a difference of 0.27 per cent and this slight difference in favor of the California soil.* This difference, however, is too small to be attributed with any certainty to any inherent difference in soil composition.

In the season of 1908-09 both high and low gluten types of wheat were grown on these plats as in the preceding year. The low-gluten Durum original was even lower than that of the preceding year, carrying but 9.43 per cent protein. The same conditions as in 1907-08 are again shown on these plats, viz., a higher development of total protein in the product in each of the plats than in the original used, the increase being about 3.50 per cent, but, *as between the two plats, there was no practical difference,* 13.23 per cent and 12.95 per cent for California and Kansas soils, respectively, or but 0.28 per cent. That of the preceding year was 0.27 per cent. In both years the slight difference was in favor of the California soil.

The high-protein original (981) used for this season was the same as that of the preceding season, and again there was a marked lowering of the protein content under the California condition. There was a greater difference in the case of this wheat than in the preceding trials, the California soil plat showing 15.07 per cent total protein and the Kansas plat 14.32 per cent; in other words, a difference of .70 per cent, again in favor of the California soil.

If now we turn attention to the alcohol-soluble nitrogen content, it will be seen that there is the same general change between the original used and the resulting product, viz., a well-defined lowering of the nitrogen in the case of the low protein type, yet, as between the two plats, such difference as occurs is, in general, in favor of the Kansas soil. In the case of the grain produced from the low-protein original, the two plats showed an essential difference, 1.18 per cent and 1.23 per cent, respectively, for California and Kansas soils. Such small difference as occurs, viz., .06 per cent, is in this case in favor of the California soil, and in each of the succeeding years, including 1909-10, this difference in alcohol-soluble nitrogen is very slight, but uniformly runs in favor of the Kansas soil. However, *the differences that occur are probably too small to be attributed to any difference in the soil characteristics, and might well come within the limits of analytical error.*

On the other hand, it is interesting to note that in the case of the salt-

soluble nitrogen such small differences as appear from the analyses, with the exception of the first season, have been in favor of the Kansas soil, but here again, as in the preceding, there is altogether too slight a difference to attribute it to the soil without a much longer series of tests.

The other constituents and the physical appearance of the grain produced on the two plats were practically identical, although the fat content has been uniformly in favor of the Kansas soil plat by about 0.2 per cent.

From these results it would appear that a normal soil has little if any influence upon the nitrogen content of the wheat kernel, but that climatic factors are the controlling ones. The experiment has been of such short duration, however, that it needs further corroboration before it can be accepted absolutely.

THE TRIANGULAR SOIL EXCHANGE EXPERIMENT.

In 1908, a year later than the experiments described in the preceding pages, a second set of soil plats were secured in coöperation with the United States Department of Agriculture, in order to broaden the scope of the experiments. These plats serve a very useful purpose as a check upon the results secured from the original plats, as well as furnishing results in an independent experiment. The Kansas soil used in the second series is from the same place and is of the same physical characteristic as that secured for the first series, as is also the Davis soil and the undisturbed check plat used in this experiment. The third plat is of soil from the Arlington farm of the United States Department of Agriculture in Maryland, and of a distinctly different type.

In this experiment the arrangement is somewhat different than in the first series, and consisted in transferring a sufficient quantity of soil from each of three experiment stations located in California, Kansas, and Maryland, to each of the others, viz., a plot, 5 feet square and 3 feet deep, of California soil was sent to each of the other two stations, and in exactly the same way plots of Kansas soil were sent to California and Maryland, and plots of Maryland soil were sent to California and Kansas. Wheat from the same original seed, supplied by the Department of Agriculture, was grown in these different soils at the three stations to ascertain the effect of the soil on the composition of the crop. There were thus four plots of soil at each station used in the experiment, two were imported soil and the other two home soil, one of which had been disturbed as were the others in shipping, and the other was undisturbed home soil. Under these conditions all the disturbing factors save those due to the soils alone were eliminated.

It must be stated that a supposition is made in the premises, namely, that the plants do not assimilate any of the constituent elements of plant food contained in the soil below the third foot. It is believed, however,

that the crop as a whole obtained its food from the food constituents contained in the first three feet of soil, although as a matter of fact in the Kansas and the Davis soil plats the wheat roots did extend below the third foot.

Observations were made to ascertain the depth the roots penetrated the soil, and it was found that in one or two instances the roots of the plants grown on the California and Kansas soil reached a depth of 42 inches. On the Maryland soil plat no plant roots were found to go beyond the first three feet. It is firmly believed that the crops as a whole obtained their food from the food constituents contained in the first three feet of soil.

It was thought at the beginning of the experiment that a cement block or metal sheet under the first three feet of soil, to prevent the roots from going to a greater depth, would cause other abnormal conditions, such as a drying-out of the soil, which would, in the end, give results no more reliable and would not be comparable with the check plat. Each plat of soil was, however, walled with California redwood.

The California soil used in the experiment is described as a Sacramento silt loam. The Kansas soil is a dark heavy loam, while the soil from Maryland is a light yellow clay. The three soils are not lacking in any of the principal plant-food constituents and have the composition given in the table below:

TABLE IX.

Percentage composition of soils.

Foot.	Nitrogen.	Phosphoric acid.	Potash.	Sulphuric acid.	Lime.	Magnesia.
California Soil.						
First	.118	.161	.49	.121	.704	.703
Second	.074	.127	.473	.053	.621	1.69
Third	.058	.124	.462	.046	.683	1.48
Average	.083	.137	.475	.073	.669	1.29
Maryland Soil.						
First	.111	.114	.342	.13	.191	.42
Second	.076	.127	.278	.111	.222	4.75
Third	.042	.111	.450	.053	.204	4.72
Average	.076	.117	.357	.098	.205	3.297
Kansas Soil.						
First	.174	.160	.602	.14	.89	1.301
Second	.121	.173	.783	.08	.796	2.29
Third	.040	.165	.902	.09	1.69	2.18
Average	.111	.166	.762	.10	1.125	1.92

NOTE.—The "Official Methods" recorded in Bulletin No. 107 (revised) of the Bureau of Chemistry, U. S. Dept. of Agriculture, were followed in making the analyses recorded in this paper.

During the first season of the experiment, 1908-09, Turkey wheat (No. 1571) was grown on the four plats of soil. This is a common winter wheat, and was supplied by the United States Department of Agriculture. Instead of using the same Turkey seed in the second season's experiment, a high protein wheat, Crimean, a common winter wheat, was used. The results obtained from these two varieties of wheat during the two seasons are given in the following table:

TABLE X.

Percentage composition of original seed and wheat produced from it on the various soil plots.

No.	Plot.	Nitrogen.	Ash.	Phosphoric acid.	Potash.	Sulphuric acid.	Lime.
	First Season—1908-1909.						
1067	Check	2.74	1.60	.842	.55	.839	.067
1066	California	2.86	1.45	.799	.529	.737	.113
1065	Maryland	2.11	1.68	1.196	.673	.603	.150
1064	Kansas	2.07	1.47	.771	.537	.544	.157
	Original Turkey Seed.*						
-----	Original	2.35	1.86	0.87	--------	0.62	0.10
	Second Season—1909-1910.						
1078	Check	2.36	1.80	.850	.567	.896	.087
1077	California	2.50	1.77	.788	.602	.687	.175
1076	Maryland	3.06	2.40	1.000	.703	.984	.110
1075	Kansas	1.97	1.68	.875	.569	.611	.197
	Original Crimean Seed.						
1074	Original	3.06	1.71	.861	.604	.894	.090

*There was not enough of this sample available to make a determination of the mineral constituents. The figures here given were furnished by Dr. J. A. Le Clerc, of the Bureau of Chemistry.

TABLE XI.

Showing approximate analysis of wheats grown on triangular soil. Exchange plats 1908-10.

	Season 1908-9.					Season 1909-10.				
	Original C. I. No. ———	Check California soil, undisturbed. No. 1067	California soil. No. 1066A	Kansas soil. No. 1064A	Maryland soil. No. 1065	Original C. I. No. 1571. No. 1074	Check California soil, undisturbed. No. 1078	California soil. No. 1077	Kansas soil. No. 1075	Maryland soil. No. 1076
Total protein	13.40	15.61	16.33	11.80	13.20	17.18	13.45	14.27	11.23	17.44
Ash	1.86	1.90	1.74	1.64	1.71	1.96	2.15	2.11	1.85	2.19
Fat	———	2.76	2.20	2.59	2.06	1.90	1.86	1.82	1.77	1.73
Fiber	———	3.40	3.33	3.45	3.44	2.26	2.36	2.69	3.02	2.92
Alcohol—Soluble nitrogen	———	1.22	1.59	.84	.92	1.35	.91	1.01	.76	1.19
Salt—Soluble nitrogen	———	.62	.48	.50	.71	———	———	———	———	———
Percentage of typical kernels	———	99.10	99.82	79.75	97.47	100.	90.4	100.	64.7	100.
Percentage of starchy kernels	———	.90	.18	20.25	2.53	———	.6	———	35.3	———
Kernels in 10 grams	———	———	303	269	356	335	347	374	300	474
Days to mature	———	272	288	208	231	299	238	253	204	317

VARIATION IN CHEMICAL COMPOSITION OF GRAIN.

The original Crimean seed which had been produced on Kansas soil in Kansas and containing a high nitrogen content, 3.04 per cent, when grown on Kansas soil in California fell to 1.91 per cent, a decrease of 1.13 per cent. The nitrogen content of the same seed remained almost exactly the same when grown on Maryland soil in California, and decreased to 2.4 per cent when grown on California soil in California. In this connection it will be noticed that the nitrogen content of the Kansas soil was the highest, while the Maryland soil contained the least amount of nitrogen. The grain produced on the Maryland soil was pinched and the yield was low, probably due to the inability of that soil to hold moisture. This fact accounts for the high nitrogen content of the grain produced on the Maryland soil. The data shows no regularity in the nitrogen content and no relation between the amount of that element in the seed and in the soil.

With the exception of the wheat grown on Maryland soil the amount of ash in the grain is fairly uniform. It will also be noticed that the potash and phosphoric acid content of the grain grown on Maryland soil during both seasons was highest, and with one exception, namely, the wheat grown on California soil, the sulphuric acid content was the highest and the phosphoric acid and potash content of the Maryland soil the lowest of the three soils. The lime-magnesia ratio of the Maryland soil is as 1:16, and it may be that this large amount of magnesium is responsible for the assimilation of the other constituents to a greater degree.

The ash and nitrogen content of the grain grown on both plots of California soil are practically the same, but the variation occurring in the other constituents is almost as great as that occurring in the grain produced on the other soils. This indicates that a disturbance of the soil to a depth lower than the ordinary depth of cultivation has a marked effect on the assimilation by the plant of the mineral elements contained therein. With such a variation occurring in the mineral constituents of the grain grown on the same soil, it would be unsafe to assume that the amount of food ingredients assimilated by the plant is in direct proportion to the available materials present in the soil.

The lime content of the Kansas soil was highest and that substance was present in a greater quantity in the grain grown on that soil. The ratio of phosphoric acid to potash is higher in the crop than in the soil. The same fact is also true of the nitrogen-phosphoric acid and nitrogen-potash ratios.

PHYSICAL APPEARANCE OF GRAIN.

A very notable difference occurs in the appearance of the grain. During the first season the grain grown on both plats of California soil, the check plat and the disturbed soil plat, was practically the same, well formed, plump kernels of a typical amber. Very few starchy kernels were noticed in either of the lots. The individual kernels were somewhat larger in the grain produced on the check plat, 285 kernels weighing 10 grams, as against 303 kernels from the disturbed soil plat. The seed produced on the Maryland soil was pinched, the grains were much smaller than those mentioned above, 356 weighing 10 grams. A few more starchy grains were observed, although the percentage was below 5 per cent.

The results of the second season showed more starchy berries (as high as 8 per cent) in the seed grown on the check plat than that grown on the other California soil plat. And, as in the previous season, the individual kernels were larger, 347 grains weighing 10 grams as compared with 374 grains. The seed from the disturbed plat was plump, a typical amber, and has high milling qualities. It contained practically no starchy grains. Again the grain on the Maryland soil was pinched, the berries were small, 474 weighing 10 grams, and practically no starchy grains were present. The seed produced on the Kansas soil contained as high as 60 per cent of starchy grains. The berries were heavier than the others, 300 weighing 10 grams. The original Crimean seed contained no starchy berries, and 335 kernels weighed 10 grams.

It is also interesting to note the amount of nitrogen present in the large and small berries. One thousand grains of the seed produced the first season on the check plat, the disturbed plat of California soil, the Maryland soil plat, and the Kansas soil plat weighed 37.4, 34.8, 27.4, and 37.1, respectively. The percentage of nitrogen in the same grain was 2.77, 2.85, 2.11, and 2.06, respectively. Expressing the amount of nitrogen in grams per 1,000 kernels we would get 1.04, .99, .58, and .76, respectively. From this it will be observed, contrary to the rule, that the smaller grains produced on the Maryland soil contained much less nitrogen than the larger grains. One thousand grains of the seed grown on the same plats the following season weighed 28.6, 29.6, 22.6, and 36.1 grams, respectively. The percentage of nitrogen was 2.48, 2.33, 3.02, and 1.91, respectively; or again representing this as grams of nitrogen per 1,000 kernels it would be .71, .69, .68, .69, respectively. It is clearly seen in this case that the different seeds, although varying considerably in size, contain practically the same quantity of nitrogen. The weight of the different constituents in 1,000 kernels is summarized in the following table:

TABLE XII.

Weight in grams per 1,000 kernels.

SEASON 1908-1909.

Plot.	Weight of 1,000 kernels	Grams nitrogen per 1,000 kernels	Grams phosphoric acid per 1,000 kernels	Grams potash per 1,000 kernels	Grams sulphuric acid per 1,000 kernels	Grams lime per 1,000 kernels
Check	37.38	1.04	.32	.21	.31	.025
California	34.77	.99	.28	.18	.26	.039
Maryland	27.42	.58	.33	.18	.17	.041
Kansas	37.1	.76	.29	.20	.20	.058

SEASON 1909-1910.

Check	29.71	.71	.25	.17	.26	.026
California	28.73	.70	.23	.17	.20	.050
Maryland	22.69	.69	.23	.16	.22	.025
Kansas	36.11	.69	.21	.20	.22	.071

Conclusions.—It must be said that the results so far obtained do not shed as much light upon the primary question as to the influence of the soil nitrogen upon the nitrogen content of the wheat as could be desired, possibly on account of the short duration of the experiment. It is evident, however, that in neither of the series of trials has the grain carrying the larger nitrogen content been obtained from the soil plat having the heaviest total nitrogen content. In the light of the present data it seems quite certain that the soil nitrogen content has very little, if any, direct influence upon the nitrogen content of grain grown upon such soil, and that some climatic factor is sufficient to entirely overshadow the soil factor. This is entirely in harmony with the work of Dr. Le Clerc previously reviewed, and also with the well known wide fluctuation of the nitrogen content of wheat from season to season, although the grain be grown upon the same soil. It may be that certain physical factors, enabling the soil to hold moisture better at certain periods of the plant's growth are responsible for the difference, but of this we have no data so far as these plats are concerned.

The results also show that a chemical analysis of a soil by the ten-hour hydrochloric acid (sp. gr. 1.115) digestion method reveals no definite relation between the chemical composition of the soil and the crop.

Further, it appears that the nitrogen content of an original seed when grown elsewhere than in a climate within which it has been acclimated, has little or no influence upon its progeny, and that even though it be acclimated still some seasonal climatic factor is sufficient to either lower the nitrogen content of a high-gluten wheat or raise the nitrogen content of a low-gluten original.

ADDENDA.

Since the preparation of the previous matter, analyses have been made of the product of the 1911 crop from the triangular soil exchange plats. For the season of 1911, the original for each of the plats and the general check consisted of the seed produced on the same plat the preceding season.

The results are stated below:

TABLE XIII.

Showing analyses of wheats from triangular soil exchange plats 1911. Interior plants.

	Check.		California.		Kansas.		Maryland.	
	Original.	1911 crop.	Original.	1911 crop.	Original.	1911 crop.	Original	1911 crop.
Total protein	13.45	12.04	14.27	10.56	11.23	9.61	17.44	13.20
Ash	2.15	1.60	2.11	1.88	1.85	1.76	2.19	1.78
Alcohol—Soluble nitrogen	.91	.93	1.01	.76	.76	.70	1.19	.80
Salt—Soluble nitrogen	.51	.50	.54	.45	.46	.47	.57	.50
Percentage typical kernels	90.40	88.80	100.00	50.8	64.7	46.0	100.00	100.00
Percentage starchy kernels	.6	11.2	------	49.2	35.3	54.0	------	-----
Kernels in 10 grams	374	261	374	289	204	265	474	425

TABLE XIV.

Showing analyses of wheats from triangular soil exchange plats 1911. Exterior plants.

	Check.		California.		Kansas.		Maryland.	
	Original.	1911 crop.	Original.	1911 crop.	Original.	1911 crop.	Original.	1911 crop.
Total protein	13.45	12.04	14.27	11.60	11.23	12.12	17.44	12.52
Ash	2.15	1.60	2.11	1.89	1.85	1.80	2.19	1.72
Alcohol—Soluble nitrogen	.91	.93	1.01	.82	.76	.90	1.19	.72
Salt—Soluble nitrogen	.51	.50	.54	.51	.46	.56	.57	.57
Percentage typical kernels	90.4	88.8	100.00	61.3	64.7	82.4	100.00	96.8
Percentage starchy kernels	.6	11.2	------	38.7	35.3	17.6	------	3.2
Kernels in 10 grams	347	261	374	289	204	269	474	269

As in the previous two seasons, the grain produced on the Maryland soil was pinched and the kernels were small, which fact again renders this product not comparable with the others.

Showing relative yield from the triangular soil exchange plats 1911.

The ash content of the produce of the check plat is markedly low when compared with the others, which are very uniform in ash content. The selected interior product of each of the California and Kansas plats shows a marked uniformity in the nitrogen and ash content as well as in the number of kernels in 10 grams, and the percentage of starchy and typical kernels. They show, however, less nitrogen than the grain from the check plat.

On comparing the chemical characteristics of the exterior plants it will be noticed that the figures in all of the columns for the grain from the check and Kansas plats agree tolerably well.

The most striking point brought out by these last figures, is the difference in composition and appearance of the grain produced on the same soil, viz.: the check plat and the other California soil plat. There is a greater difference between these two products than exists between the others or between these and the others. This difference, particularly with respect to the nitrogen, is not nearly so great, however, as that brought out by Le Clerc (*loc. cit.*) from his experiments in which both soil and climate were variable factors. It does, however, indicate that some other factors pertinent to the physical or biological conditions of the soil play an important rôle since we have, in our own experiment, only one variable factor, viz.: the soil. Moreover, the slight variations occurring in the chemical characteristics in these experiments, being considerably less than those observed by Le Clerc, adds strongly to the belief that the climatic factor is the chief one in producing changes in the chemical composition of wheat.

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